

FORTY YEARS OF *UBV* PHOTOMETRY AT HVAR

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Abstract. The history of the program of systematic *UBV* photometric monitoring of Be stars, binaries, CP stars and some other targets is briefly summarized. It is shown that a careful data homogenization, reduction and transformation to the standard Johnson system can be carried out successfully even at a station nearly at the sea level when some strict measures are taken.

Key words: *UBV* photometry - Be stars - binaries

1. Motivation

Our original goal was to discover some eclipsing binaries among Be stars to support of the binary hypothesis of the origin of the Be phenomenon (Harmanec et al. 1972; Kříž and Harmanec 1975). The *UBV* observing program was started immediately after the installation of the 0.65-m reflector on July 29, 1972 and has continued until now, with a number of Croatian, Czech and other observers participating. The program was parallel to spectroscopic monitoring of Be stars in Ondřejov. Soon we found that the Be stars vary on several timescales, the dominant being long-term changes on a timescale of years but often with quite a small amplitude. Therefore, there was a need for a very careful transformation to the standard Johnson system. The following *non-linear seasonal transformations* are a must (see Harmanec, Horn and Juza 1994 and references therein for details):

$$\begin{aligned} M_{\text{stand.}} - M_{\text{instr.}} &= H_1(B-V) + H_2(U-B) \\ &+ H_3(B-V)^2 + H_4(B-V)^3 + H_5, \end{aligned} \quad (1)$$

where M stands for V , B , and U and H_j are the seasonal transformation coefficients (different for each passband). The second crucial step was to

homogenize but not to re-define original Johnson *UBV* magnitudes of many stars. This way, our comparison, check and red standard stars can be used as seasonal transformation standards. The whole package of reduction programs with HEC22, VYPAR, auxiliary programs, a detailed manual, and practical examples is available at <http://astro.troja.mff.cuni.cz/ftp/hec/PHOT>. The reduction program HEC22 is also able to model the changes of extinction during observing nights, which greatly improves the accuracy of all-sky photometry, therefore also the seasonal transformations - see Figure 1. The second order extinction coefficients are derived among the *seasonal* transformation coefficients, not every night, since they are given by the transmission properties of the instrument, not the atmosphere of the Earth.

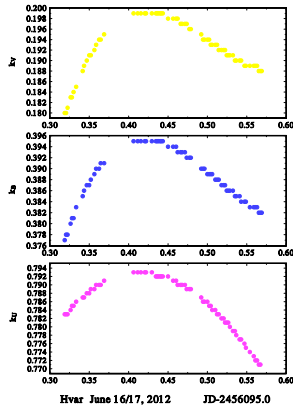


Figure 1: The variation of extinction coefficients during one observing night at Hvar. We found similar changes even for observations from Sutherland or La Silla.

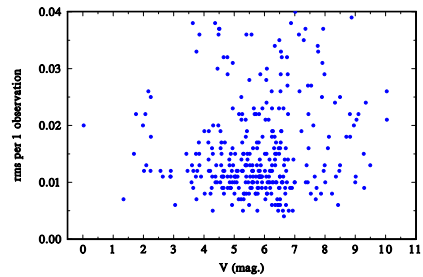


Figure 2: A plot of the rms error per 1 observation for all observations from the Hvar differential archive from the years 1972 to 2012. The lower envelope of this plot shows that non-variable stars have the rms errors per 1 observation less than 0^m.01 for all stars brighter than, say 8th magnitude. For data obtained after 1990, this limit is probably a bit lower.

2. Statistics

It is obvious that choosing a site for a photometric observatory, located only 240 m above the sea level on a relatively small island and not very far from a city of Hvar is, well, somewhat unusual. We hope we may, after 40 years of a successful operation, quote the words of the former director of the

Astronomical Institute of the Academy of Sciences in Ondřejov Dr. L. Perek. When he first climbed the ‘goat trail’ to the observatory and looked around, he said: “*It is a nonsense to built an observatory here... but what a marvelous one!*” Our task was to give sense to this nonsense and we hope we did... The number of publications in refereed journals and a simple statistics show that quite clearly. Our approach led to a ‘rehabilitation’ of the *UBV* system: Applying reductions with **HEC22**, we were able to combine the data from Hvar (240 m above the sea level) and San Pedro Mártir (2800 m above the sea level) *without need for any artificial zero-point shifts*. How well the *UBV* magnitudes from different stations can be reproduced is illustrated by Table 1, adopted from Božić et al. (2007).

Table 1 Mean differential *UBV* values of the check star φ Her (HD 145389) relative to v Her from individual stations and observing seasons, illustrating the level of homogeneity of our transformations to the standard system.

Station	Mean epoch (HJD-2400000)	Year	N of obs.	V (mag.)	$B-V$ (mag.)	$U-B$ (mag.)
Hvar	45072.6	1982	99	4.252 ± 0.008	-0.064 ± 0.008	-0.248 ± 0.011
Hvar	51377.2	1999	5	4.257 ± 0.007	-0.062 ± 0.009	-0.248 ± 0.013
Hvar	52305.2	2002	139	4.254 ± 0.006	-0.062 ± 0.008	-0.252 ± 0.008
Hvar	52691.4	2003	42	4.255 ± 0.007	-0.061 ± 0.010	-0.255 ± 0.010
Hvar	53039.0	2004	96	4.254 ± 0.005	-0.061 ± 0.005	-0.253 ± 0.006
Hvar	53370.2	2005	78	4.257 ± 0.006	-0.064 ± 0.006	-0.252 ± 0.006
San Pedro	52608.7	2002	48	4.259 ± 0.007	-0.062 ± 0.007	-0.247 ± 0.007
San Pedro	52750.7	2003	28	4.257 ± 0.006	-0.061 ± 0.007	-0.249 ± 0.005
Hipparcos	48078.1	1990	43	4.248 ± 0.004	all-sky	
Hipparcos	48377.8	1991	45	4.249 ± 0.005	all-sky	
Hipparcos	48700.0	1992	24	4.249 ± 0.004	all-sky	
Hipparcos	49046.7	1993	6	4.246 ± 0.007	all-sky	
Tubitak	52764.7	2003	35	4.253 ± 0.007	-0.062 ± 0.006	-0.244 ± 0.009

It turned out that in the years when it was possible to carry out observations in the course of the whole year (1981 and 1982), thanks mainly to the enthusiasm of (at that time) youngsters Krešo Pavlovski and Hrvoje Božić, it was possible to obtain usable photometry on more than 100 nights per year. The current number of about 70 nights per year is mainly due to the lack of manpower. The latest edition of the Hvar archive of differential observations from April 2012 contains 75667 observations for 682 different stars. Figure 2 is a plot of a rms error of 1 observation from that archive. For

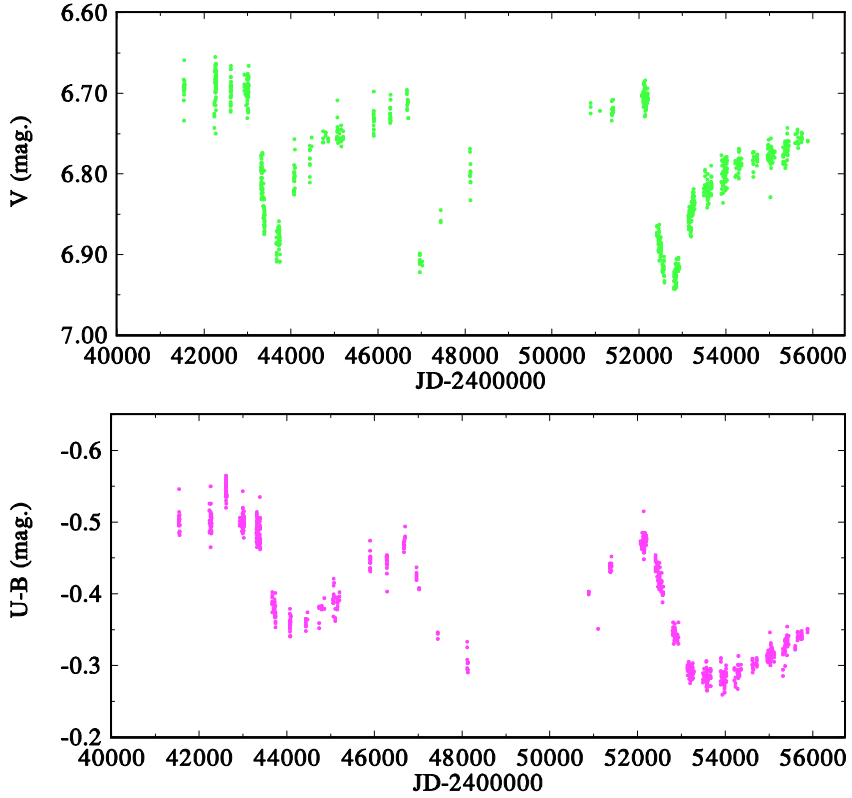


Figure 3: Forty years of monitoring of the secular light and colour changes of the spectroscopic binary with a B7e primary V744 Her = 88 Her, the very first SB discovered with the Ondřejov 2-m telescope. The data cover three consecutive shell and emission-line episodes and the plot is based on unedited individual observations from the Hvar archive. The gap in coverage is due to war years in the former Yugoslavia.

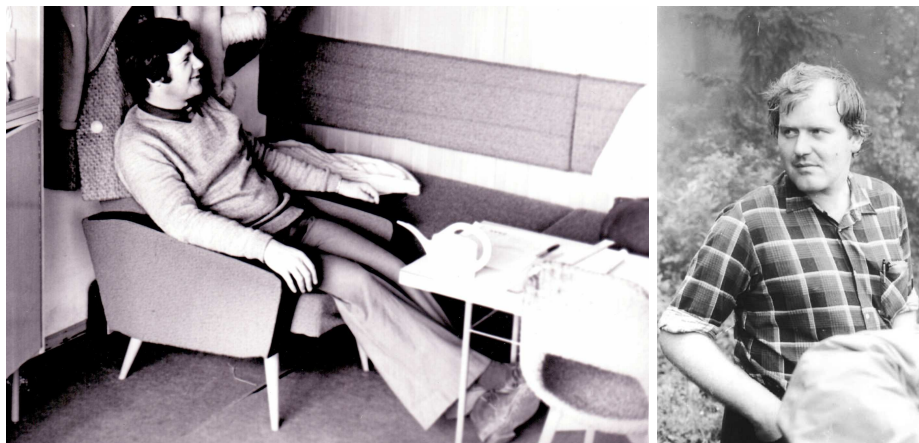


Figure 4: To the memory of our friends and colleagues Dr. Jiří Horn (left) and Karel Juza (right), who both passed away in 1994. Besides observing at Hvar, Jiří wrote the control program of the photometer PEHVAR and the program VYPAR, which handles the data archives, while Karel did the substantial parts of the homogenization of *UBV* magnitudes after the first two decades of *UBV* observations at Hvar.

non-variable stars this error amounts to less than $0^m.01$ in *V*, being similar in *B* and slightly higher in *U*.

3. Results

The original instrumentation and reduction strategy are described in the paper by Harmanec et al. (1977). Results of the first 25 years of observations in the Be program were summarized in detail by Pavlovski et al. (1997). For the more recent results in the Be program, see the summary paper by Božić, Koubský and Harmanec here.

The power of systematic observations with a simple instrumentation but a very careful observational strategy and data reduction is well illustrated by Fig. 3. Not many similarly systematic series of observations exist.

Besides Be stars, some observations were also devoted to observations of CP stars and in recent years, the main focus has shifted to studies of astrophysically interesting binary and multiple stars (cf., e.g., Nemravová et al. here).

We wish to dedicate this contribution to the memory of our good friends

and colleagues Drs. Jiří Horn and Karel Juza – see Fig. 4.

Acknowledgements

The accumulation of the large number of observations would be impossible without patient and tedious work of a large number of observers, most of them from Croatia and Czech Republic but also of craftsmen from the Ondřejov mechanical workshop led by K. Havlíček, Dr. P. Mayer, who designed the telescope and photometer and a number of other technicians and servicemen from both countries who could not be mentioned explicitly due to limited space. We, however, wish to thank to Dr. V. Ruždjak, the Director of the Hvar Observatory, for his continuing support to this project. The research of PH was supported by the grant P209/10/0715 of the Czech Science Foundation.

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